CHAPTER 32

INTRODUCTION

The LHC physics programme is mainly based on proton-proton collisions. In addition, shorter running periods, typically one month per year, with heavy-ion (lead) collisions are included in the programme [1, 2]. While lighter ions are considered as well, the baseline scheme deals with Pb ions, because they are the most difficult to produce and most rewarding in terms of physics results. Therefore this report almost exclusively deals with Pb ions.

At present, a fixed-target ion experimental physics programme is still in full swing at the SPS. Naively, one would assume that this fixed-target acceleration scheme (Linac3 - PS Booster - PS - SPS, [3]) may be well adapted to fill the LHC. It corresponds to the proton injector chain, but of course with Ion Linac3 replacing Proton Linac2. The problem is that, contrary to the protons, the required LHC Pb ion phase-space density cannot be achieved via the PS Booster, the fixed-target Pb beam falling short by a factor of ~30 in terms of beam brightness and ~1000 in terms of luminosity in the LHC. This factor 30 can be gained in essentially two ways: first, by an ion source with an instantaneous current 30 times higher than the one generated by the present ECR (Electron Cyclotron Resonance) source; second, by phase space cooling.

An initiative to develop an extremely high-intensity, short-pulse ion source based on a high power CO_2-laser, the “Laser Ion Source” study at CERN [4], has been discontinued recently, because the few results obtained so far, though interesting, are still far from satisfying the stringent beam requirements called for by the LHC. Another type of source, pioneered by BNL for RHIC, the Electron Beam Ion Source (EBIS), has enjoyed spectacular progress in recent years, but would still need a lengthy upgrading programme to meet LHC specifications, too risky for the start-up of LHC with Pb ions, scheduled for April 2008.

CERN has a long-standing experience in phase-space cooling. In particular, electron cooling, ideally suited for fast cooling of highly-charged ions at low (~MeV/n range) energies, was pioneered in LEAR (Low Energy Antiproton Ring, mothballed in 1997) and is a key ingredient of the so successful AD (Antiproton Decelerator). These are the reasons why CERN’s baseline scheme to produce Pb ions for the LHC is based on LEIR (Low Energy Ion Ring), the LEAR machine after upgrading. In this scheme, initially proposed in 1993 [5], several long (~200 μs), low-intensity pulses from Linac3 (albeit improved by a factor two after source upgrading) are transformed into short (~200 ns), high-intensity, small-emittance bunches by accumulation and cooling in LEIR, before being accelerated and sent to the PS. In this latter machine, two such bunches are transformed, on flat porches during acceleration, to four bunchlet pairs by extremely elaborate RF gymnastics. The distance between pairs is 100 ns, the LHC bunch spacing. Eight to thirteen such PS pulses are accumulated during an SPS injection plateau and then accelerated in the SPS; before extraction to the LHC, the bunchlet pairs are recombined to nominal LHC bunches.

A series of tests with Pb ions on LEAR in 1997 has successfully demonstrated the feasibility of the accumulation/cooling scheme, with a missing factor of ~3 compared to LEIR requirements [6]. The upgrading programme from LEAR to LEIR (~3/4 of the project resources), with adaptation work also in Linac3, the PS and SPS machines (together ~¼), is aimed at improvements which make up for the missing factor.

In the following chapters, the proposed upgrading programme [7, 8], called “Ions for LHC” (I-LHC) project, is presented, with particular emphasis on matching the natural performance limitations of the injector chain to the LHC baseline Pb ion beam request. Accompanying the beam along the injector chain, beam dynamics aspects are discussed and the ensuing hardware upgrading programme is presented. An important aspect to keep in mind is the short delay imposed by a rather late decision on the ion injector chain. Therefore, the scheme presented here has not undergone a full optimisation process. However, there is confidence that the parameters chosen are not far from the best possible ones.

Even after upgrading, the ion injector chain will be subject to basic limitations whose impact on the performance is not always easy to predict. Some of these limitations are rather hard-edged and well defined, others will only be known after commissioning of the accelerators concerned, including the LHC. In order to enable some learning process with reduced risks, an Early Lead Ion Scheme has been devised. While keeping to the nominal bunch population (7×10^7 Pb ions at collision), the number of ion bunches is cut down to 60 (compared to 600 for the nominal baseline scheme) and the luminosity to 5×10^{25} (instead of the baseline luminosity of 10^{27} $cm^{-2}s^{-1}$). Not only do the users accept this low initial luminosity which still enables early discoveries, but also the task for the injector chain is substantially easier, with malfunctions having less dramatic consequences in the LHC rings.

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